

**Title:** *An Overview of NASA's IM&S Verification and Validation Process Plan and Specification for Space Exploration*, Robert M. Gravitz, The Aegis Technologies Group, Inc., and Joseph Hale, NASA MSFC

**Abstract.**

NASA's Exploration Systems Mission Directorate (ESMD) is implementing a management approach for modeling and simulation (M&S) that will provide decision-makers information on the model's fidelity, credibility, and quality. This information will allow the decision-maker to understand the risks involved in using a model's results in the decision-making process. This presentation will discuss NASA's approach for verification and validation (V&V) of its models or simulations supporting space exploration. This presentation will describe NASA's V&V process and the associated M&S verification and validation (V&V) activities required to support the decision-making process. The M&S V&V Plan and V&V Report templates for ESMD will also be illustrated.



# ***An Overview of NASA's IM&S Verification and Validation Process Plan and Specification for Space Exploration***

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# ***ESMD IM&S VV&A Prime Directive***



Pre-decisional DRAFT

**Centralized oversight and decentralized execution of IM&S VV&A activities across ESMD to increase credibility and reduce risks associated with decisions based on M&S.**

**IM&S VV&A is the complement to the overall IM&S Strategy!**



# The Core Process of IM&S VV&A



Pre-decisional DRAFT

## VERIFICATION

The process of determining that a model [or simulation] implementation and its associated data accurately represents the developer's conceptual description and specifications... *Did we build that thing right?*

"It works as I thought it would."



Developer  
Verification Agent

## VALIDATION

The process of determining the degree to which a model [or simulation] and its associated data provides an accurate representation the real world from the perspective of the intended uses of the model or simulation... *Did we build the right thing?*

"It looks just like the real thing."



Functional Expert  
Validation Agent

## ACCREDITATION

The official certification that a model or simulation or federation of models and simulations and its associated data is acceptable for use for a specific purpose... *Should it be used?*

"It suits my needs."



Requester/User  
Accreditation Agent

An underlying implicit principle is Creditability: Can It be trusted?





# Purpose of IM&S

Pre-decisional DRAFT

- **Modeling and Simulations (M&S) are Integral to every aspect of the ESMD Program** (*Program -> Projects -> Components*)
  - Cost Analysis
  - Risk Assessments
  - Planning
  - Requirements Definition
  - Test and Verification
  - Technology Evaluation
  - Training
- **Effective Management of M&S has several key Objectives**
  - Provide Timely Trusted Data for Decision Makers
  - Reduce Lifecycle Cost and Risk
    - Better requirements, designs, tests, training
  - Minimize Slips in Schedule
    - Timely data for decision makers to support Prioritizing Efforts

**Institutionalizing M&S Management and  
VV&A Practices Early is Critical to Long-Term Success**

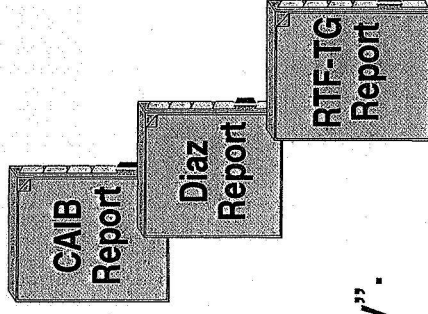


# Additional Influences



Pre-decisional DRAFT

- Numerous Reports Have Identified Significant Issues with the Use (misuse) of M&S within NASA
  - Ineffective use, access, and “outright misuse”
  - Need for Validated M&S Tools
  - Need for Management of M&S tools across Agency
- FY’05 Congressional Direction for NASA to establish a M&S Strategy and Implementation
  - “... develop and implement an integrated system simulation strategy”.



**NASA Must Address The Management (Development, VV&A and Use) of M&S!**



# ***Current Situation***

Pre-decisional DRAFT

- **Multiple Levels of new Management (L1-L3)**
- **Aggressive Development Schedule with Independent Milestones**
- **Involvement of Multiple Centers**
  - Each vying for \$
  - Each with Own M&S Tools, Processes, and Capabilities
- **Wide Spectrum of M&S Tools**
  - Project Needs are being Identified and Developed Independently
  - Tool Funding Path is not aligned to ESMD Management Structure
  - Redundancy in Capability is Common
  - Leveraging Existing Capabilities is based on self Discovery
  - Gaps in Capability Exist
  - VV&A is Rare – Trust in Analysis Results is based on Individuals.
  - Impact of VV&A is Imposing if Required Uniformly Across ESMD

**Need to Establish a “Common Sense” VV&A Approach**



# ***Recommended Approach***

Pre-decisional DRAFT

- **Establish a Unified Paradigm for the VV&A of M&S throughout ESMD**
  - Centralized Guidance with Decentralized Execution to:
    - Define M&S and VV&A Policy
    - Define standards (e.g. interface, interoperability, data)
    - Develop M&S Management Roles/Responsibilities to be levied on existing Program/Project Management Structures
    - Require Program and Projects to Develop M&S Support Plans
      - Document the Use of M&S in support of Program and Project Level Activities.
      - Identify M&S Gaps and Overlaps to support future development needs/priorities.
      - Mandate Risk Based VV&A Implementation – 5 Levels (High risk = significant VV&A).
  - Facilitate Communication of M&S Capabilities across ESMD through an M&S Resource Repository (Metadata of accredited M&S).

**Goal: Establish Effective M&S VV&A Policy and Practices Supporting Space Exploration!**



# IM&S VV&A Technical Working Group (TWG)



Pre-decisional DRAFT



Roles	Function
IM&S VV&A TWG Lead	<ul style="list-style-type: none"><li>• POC for VV&amp;A Planning Guidance</li><li>• Oversee assimilation of VV&amp;A into program planning</li><li>• Oversee outreach and indoctrination activities across ESMD</li><li>• Oversee and manage MSRR</li></ul>
IM&S VV&A Brokers	<ul style="list-style-type: none"><li>• Conduct VV&amp;A Outreach</li><li>• Oversee/audit VV&amp;A Planning and Activities</li><li>• Review and approve VV&amp;A products</li><li>• Assess M&amp;S PM manage agents</li><li>• Collect metadata for MSRR</li><li>• Representative in SE&amp;I and T&amp;E planning activities</li></ul>

**IM&S VV&A Technical Working Group is the Market Bringing Together  
M&S Sponsors, Users, Developers and VV&A Agents!**





# Overview of IM&S VV&A Roles and Responsibilities



Pre-decisional DRAFT

## IM&S VV&A TWG Lead & VV&A Brokers

- **Define and maintain policy** guidance and directives for ESMD IM&S VV&A
- **Conduct** VV&A Outreach
- **Assign** VV&A TWG Support
- **Support** M&S Risk Assessment
- **Develop** Simulation Capability Documentation
- **Assist** in developing Accreditation and V&V Plans and Reports
- **Develop** Simulation Capability Documentation
- **Concur** on all
  - Accreditation Plans
  - V&V Plans
  - V&V Reports
  - Accreditation Reports
  - Data V&V Reports

## Users, Accreditation Agents, V&V Agents, & SMEs

- Support M&S Risk Assessment
- Develop Accreditation Criteria
- Develop Accreditation Plans
- Develop V&V Plans
- Develop V&V Reports
- Conduct V&V program
- Conduct Data V&V
- Develop Accreditation Reports
- Develop Accreditation Memoranda

**Clear Demarcation of IM&S VV&A Roles and Responsibilities.**



# Key Players of IM&S VV&A Process



Pre-decisional DRAFT

Roles	Function
M&S User	<ul style="list-style-type: none"><li>• Identify and defines need for M&amp;S to solve problem or make decision.</li><li>• Define M&amp;S requirements,</li><li>• Define Accreditation criteria,</li><li>• Intended use,</li><li>• Makes accreditation decision,</li><li>• Accepts the results.</li></ul>
M&S PM	<ul style="list-style-type: none"><li>• Planning and Managing resources for M&amp;S development</li><li>• Direct overall M&amp;S effort</li><li>• Oversee CM and maintenance of simulation</li><li>• Manage modification effort of legacy M&amp;S</li></ul>
M&S Developer	<ul style="list-style-type: none"><li>• Constructing or modifying the M&amp;S</li><li>• Prepare the data used in M&amp;S</li><li>• Provide technical expertise on M&amp;S capabilities</li></ul>



# Key Players of IM&S VV&A Process Continue



Pre-decisional DRAFT

Roles	Function
<b>M&amp;S V &amp;V Agent</b>	<ul style="list-style-type: none"><li>• Provide evidence of M&amp;S fitness for intended use by ensuring that all VV&amp;A tasks are properly carried out.</li></ul>
<b>M&amp;S Accreditation Agent</b>	<ul style="list-style-type: none"><li>• Conduct accreditation assessment</li><li>• Provides guidance to the V&amp;V Agent to ensure all necessary evidence is obtain of M&amp;S fitness</li><li>• Collects and assess the evidence</li><li>• Provides the results to User</li><li>• Make accreditation decision (i.e. accreditation authority)</li></ul>
<b>M&amp;S Proponent</b>	<ul style="list-style-type: none"><li>• Manage M&amp;S throughout the lifecycle</li><li>• Configuration Control of official version</li><li>• Maintain and enhance capability</li><li>• Manage usage, protect from damage and misuse</li></ul>
<b>SME</b>	<ul style="list-style-type: none"><li>• An auxiliary role that contributes to VV&amp;A effort</li><li>• Recognized authority in specific area or discipline</li><li>• Help user establish requirement and acceptability criteria</li><li>• Participate in V&amp;V and Accreditation assessment activities as needed</li></ul>





Pre-decisional DRAFT

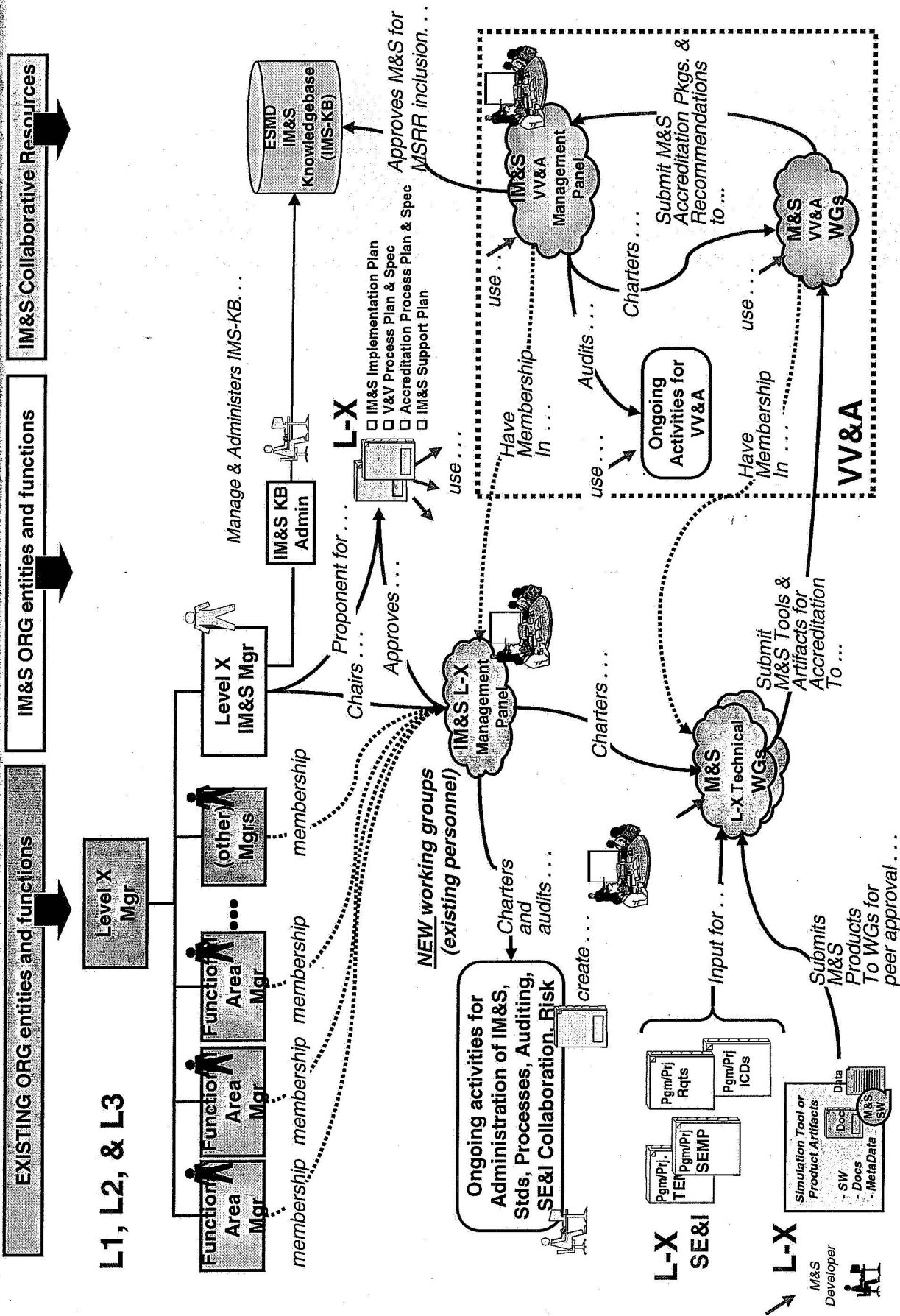
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# IM&S Functional Roles & Responsibilities @ Levels 1, 2, & 3



Pre-decisional DRAFT

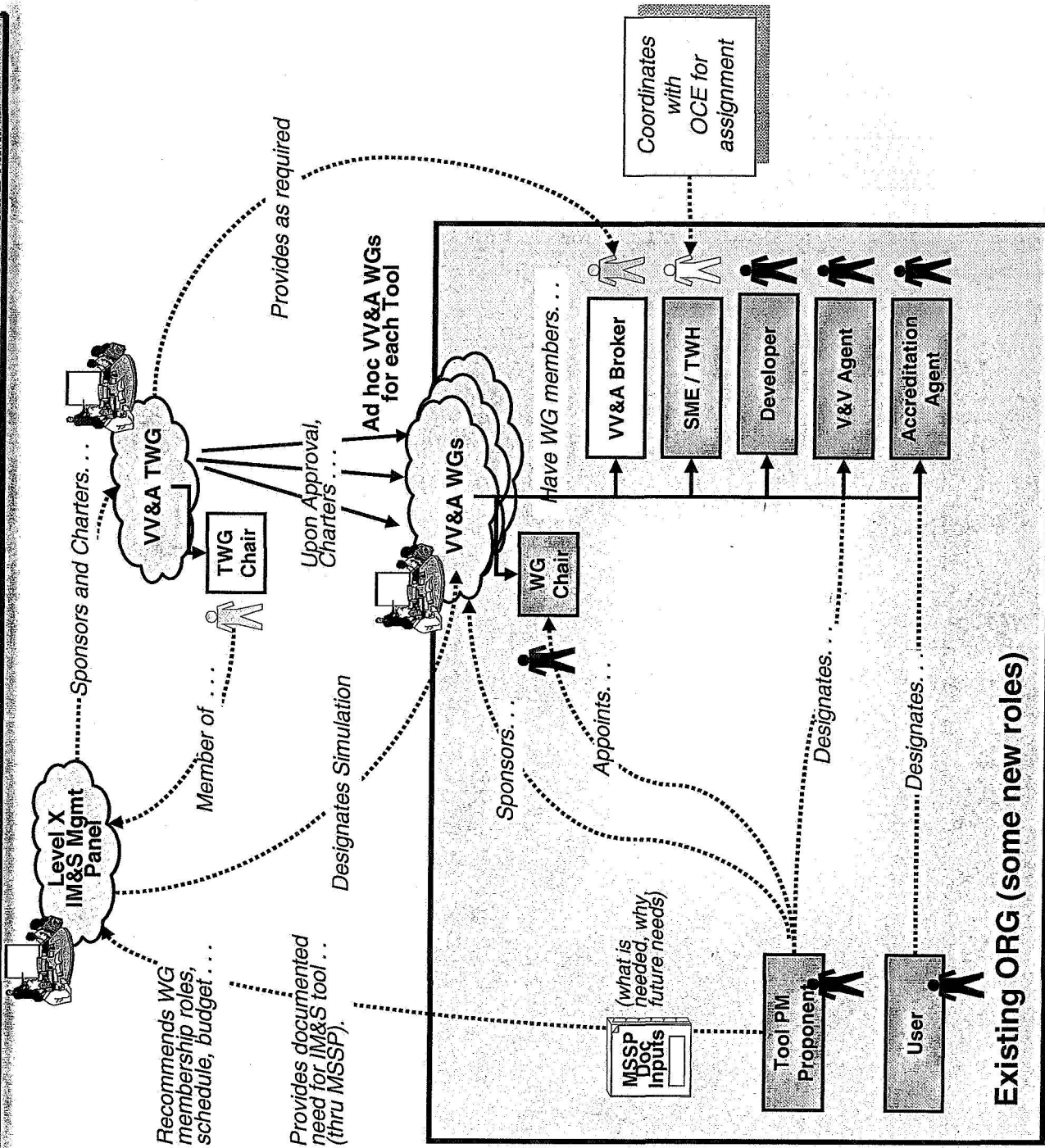
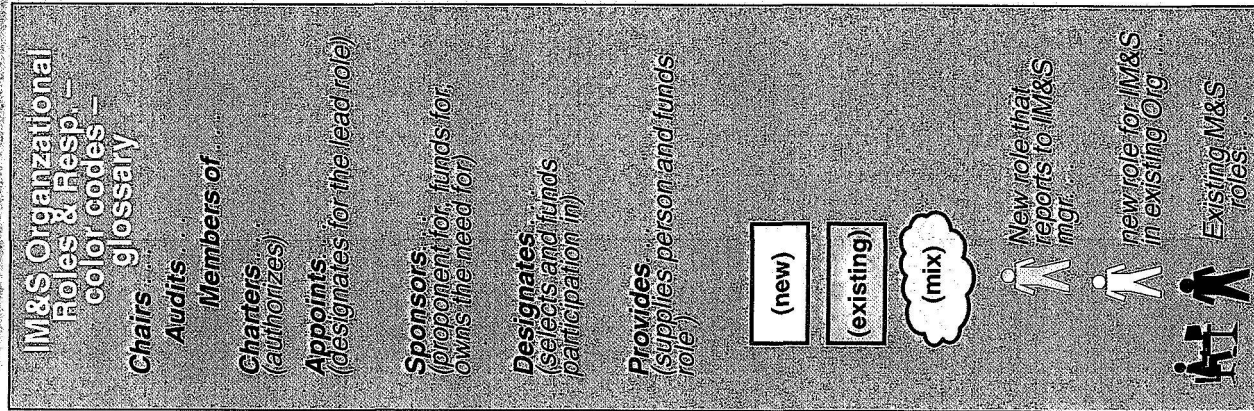




# Roles & Responsibilities Within the IM&S VV&A TWG



Pre-decisional DRAFT







# IM&S VV&A Activity Planning Process



Pre-decisional DRAFT

- The first step in the V&V Planning process addresses IM&S credibility requirements (that is, identifying the credibility requirements of the Accreditation Authority).
- The Accreditation Process Plan and Specification provides details for accomplishing a M&S risk assessment.
- The risk assessment will establish the extent of V&V that is to be done and the depth and volume of documentation and artifacts that must be present to support the accreditation process and formal accreditation decision

ESMD M&S Accreditation Process Plan and Specification  
Baseline Version 2.0  
STAFFING DRAFT – FOR REVIEW AND COMMENT

## Modeling and Simulation (M&S) ACCREDITATION PROCESS PLAN AND SPECIFICATION

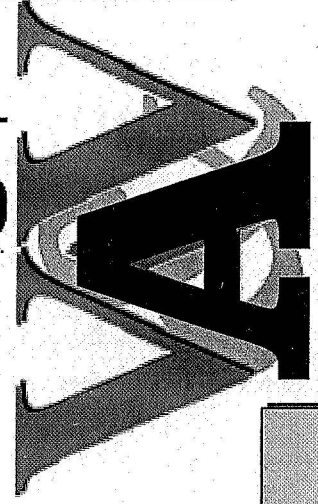
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March 9, 2006

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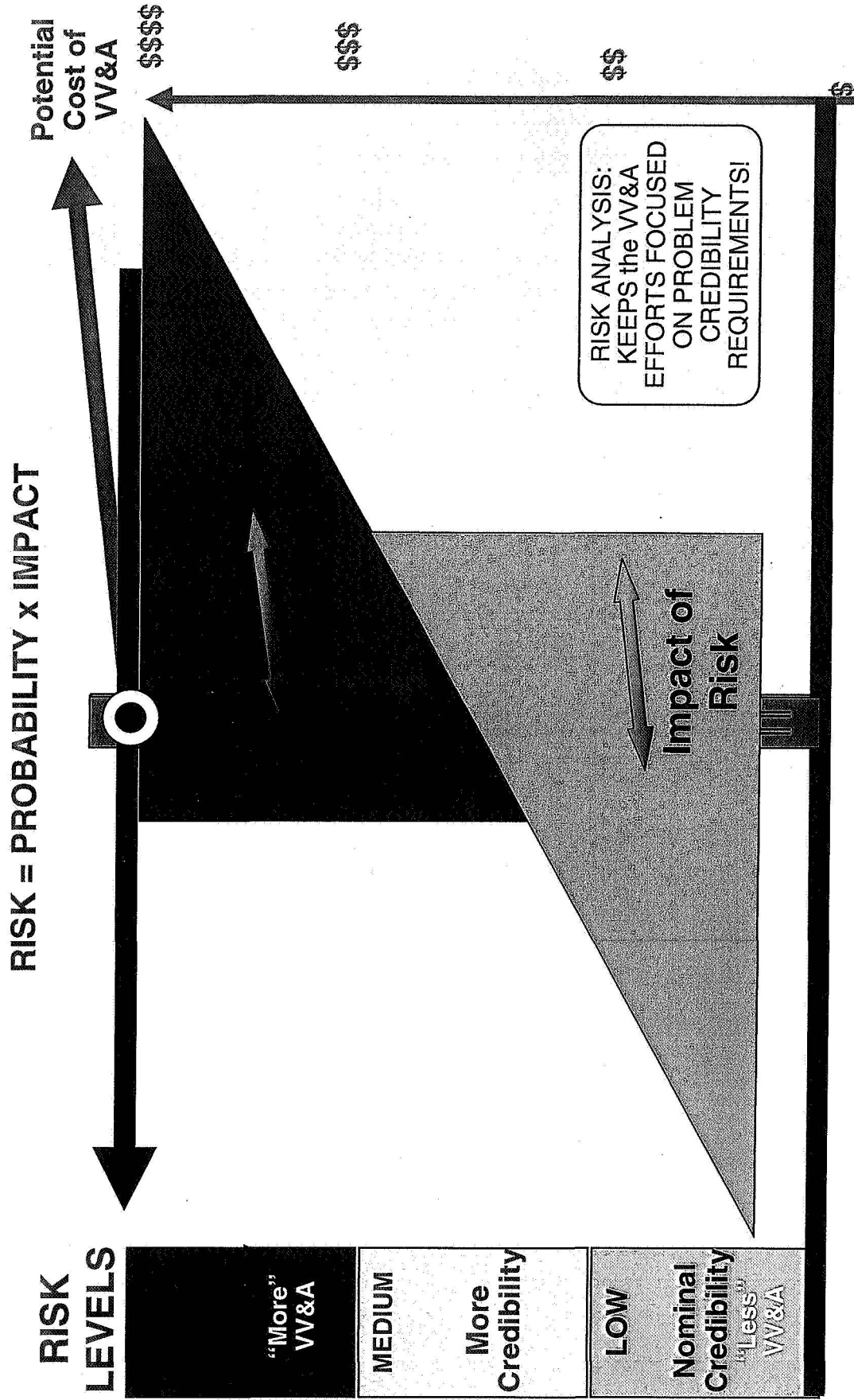


Putting the A in Front of V&V!



# The Role of Risk Analyses

Pre-decisional DRAFT



Risk analyses determine the best use of all the VV&A resources available by addressing the risks inherent in the acceptance and use of M&S data.



## Pre-decisional DRAFT

- ## •The IM&S Accreditation Process Plan and Specification

- Provides details relating to the accreditation planning
- Addresses the multi-dimensional nature of the V&V program inherent with implementation of tailored Accreditation Support Packages (V&V products suites) that are based on:
  - Accreditation Level (~Risk Level): I (Low)
  - Accreditation Level (~Risk Level): II (Medium) or
  - Accreditation Level (~Risk Level): III (High)

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# VV&A is a M&S Risk Mitigation Program

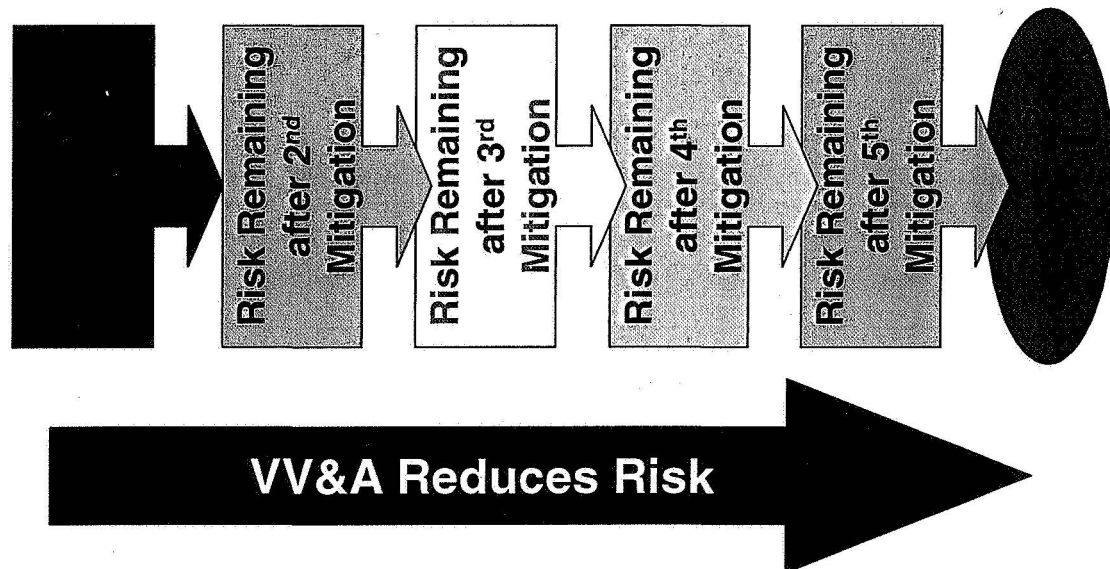


Pre-decisional DRAFT

## In a Perfectly Engineered World,

### M&S V&V Will:

- 1] Facilitate better program decisions and control throughout the life cycle by independent assessment and verification of requirements.
- 2] Enable assessment and review of M&S component designs throughout their life cycle.
- 3] Prevent Development Risk of over-investing in simulations that are good enough for their intended use.
- 4] Ensure adequate simulation-quality to enable virtual test and evaluation of digital representations of systems, thus saving on expensive physical system testing, and allowing test across otherwise impractical conditions.
- 5] Guard against use of a simulation outside its designed operational space, by verification of assumptions, caveats, and data-generation limitations.



**M&S VV&A activities contribute to reducing program risks.**





# NASA IM&S V&V Process Plan and Specification



Pre-decisional DRAFT

- The next step in the V&V Planning process addresses the identification of the V&V requirements.
- The V&V Process Plan and Specification provides the details of the ESMD M&S V&V enterprise, which are based on industry best practices as captured in:
  - Department of Defense, Modeling and Simulation Office (DMSO) Recommended Practices Guide (RPG), and
  - U.S. Navy's Joint Accreditation Support Activity (JASA) Accreditation Support Package (ASP) specification.

ESMD M&S V&V Process Plan and Specification  
Baseline Version 2.0  
STAFFING DRAFT - FOR REVIEW AND COMMENT

## Modeling and Simulation (M&S) VERIFICATION AND VALIDATION (V&V) PROCESS PLAN AND SPECIFICATION

Exploration Systems Mission Directorate  
(ESMD) NP-21

March 9, 2006

Baseline Version 2.0



National Aeronautics and Space Administration  
Marshall Space Flight Center  
Huntsville, Alabama

Establishes Expectations and Provides Guidance for V&V Planning and Execution.





# ***Key Elements Addressed In IM&S V&V Planning Process***

Pre-decisional DRAFT



- The key elements to establish M&S credibility include:
  - Capability: Identifying the functional representations within the M&S; that is, what the M&S does (and what it does it not do).
  - Correctness:
    - Software Correctness: Identifies errors in the software (determined by verification tasks)
    - Results (Output) Correctness: Identifies how well the M&S compares with “real world” data
  - Fitness of Purpose: Identifying those aspects of the M&S that support the intended use(s).
  - Usability: Identifying those features of the M&S that ensure the user does not misuse the M&S (documentation, user groups, etc.).
  - Data correctness: Identifying the completeness and confidence in both input and embedded M&S data.

**These Elements of M&S Credibility Are Addressed in IM&S V&V Planning.**